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Abstract

Current environmental problems increasingly call for research - as well as education - which crosses the traditional divides between well-established scientific disciplines and between the natural sciences, technical sciences, social sciences and the humanities. This paper addresses the issue of what interdisciplinarity, at the interface between the natural and human sciences, entails and the theoretical problems and obstacles interdisciplinarity encounters. A number of attempts to institutionalize interdisciplinarity, at the Human-Environment interface, in 'fields of study' or even 'disciplines', are briefly discussed, including Geography, Human Ecology, Environmental Studies, Environmental Management, Ecological Economics, Sustainability Science and Earth System Science. Key problems of carrying out interdisciplinary research are identified, including differences of both an ontological, epistemological and methodological nature. Particular attention is paid to differences between disciplines in the way they 'explain' and 'interpret' phenomena and regularities, and in 'world-views', pre-analytic assumptions and in time scales.

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Introduction

Science and scientists are traditionally organized in disciplines, some of which have long histories. Many present day challenges cannot be confined within the boundaries of the traditional disciplines, however. Consequently, a growing number of scientific activities cross these boundaries, giving rise to terms such as multi-disciplinary, interdisciplinary and trans-disciplinary research. While these terms are widely used to describe research activities, in most universities traditional disciplinary boundaries are preserved and provide the basic underlying structure for both research and education.

The idea of institutionalizing interdisciplinarity in academia is ancient. We will focus on one specific domain, that of Human-Environment (or Society-Nature) relation. Within this domain one can find a number of more or less interrelated attempts to organize interdisciplinary studies of human beings' interaction with their environment. Some of these studies are done more or less *ad hoc*, whereas others are organized within interdisciplinary constructs such as 'Human Ecology,' 'Ecological Economics,' 'Environmental Studies,' and 'Sustainability Science'. Geography may be the most prominent example of a 'traditional' discipline attempting to cover Human-Environment relationships.

The objective of this paper is to discuss some of the basic problems of inter- or transdisciplinarity (Max-Neef, 2005). (We will not distinguish between the two concepts here, but only separate both from multidisciplinarity, the mere adding of non-integrated studies from different disciplines). The problems encountered may crudely be classified a 'sociological', 'institutional' and 'epistemological'. The sociological problems stem from the fact that all researchers with a background in a specific discipline have been socialized to accept certain studies as models, based on the right kinds of standards, representing the right kind of view-point. These model studies are internalized early in the study of any discipline, along with a number of pre-analytic assumptions about what counts as good science. Models, standards and view-points differ across disciplines, however, and we will claim that several of the problems with inter- and trans-disciplinarity reflect this fact. The institutional problems are related to the inertia of academia, including both the established disciplines and universities. The epistemological problems relate to differences in accepted types of explanation and pre-analytic assumptions across disciplines and across the natural and social sciences.

Interdisciplinarity obviously presumes the existence of disciplines. Most of the widely accepted scientific disciplines have a century- of even millennium-long history, and this legacy has shown great robustness. It is not evident, even unlikely, that a fundamental reorganization of academia would lead to the same set of disciplines. We will not attempt to review, explain or discuss this set of standard disciplines, just note that they do not necessarily reflect current challenges, which is one reason why new interdisciplinary fields of study are continuously appearing. The study of 'the environment' or 'the Human-Environment interface' is one area in which the traditional disciplines often fail to provide a proper framework for scientific activity.

Interdisciplinarity may be an attribute of the activities of an individual scientist, a research project, a research group or an institution, in a broad sense of the term. In this paper we will mainly focus on the latter. However, it is worth noting that 'interdisciplinary individuals' are as important as institutions, yet to an increasing extent interdisciplinary individuals are products of interdisciplinary institutions, such as masters programs, research centers etc.

'Interdisciplinary constructs' in the Human-Environment domain: A brief overview

Many attempts have been made to institutionalize inter- or transdisciplinarity as separate 'interdisciplinary constructs' or even 'disciplines'. This is particularly the case in relation to the Human-Environment relationships, where borders between the traditional disciplines are constantly challenged. In the following we will give a brief overview of some 'constructs' at the Human-Environment interface. The selection of constructs discussed has been guided both by their historical role (especially as concerns Geography and Human Ecology) and by the current roles they play in the reorganization of academia to cater for the challenges associated with global environmental change. The only 'traditional' discipline discussed is Geography, since it has a long tradition of including and (sometimes) integrating elements from both natural and human sciences.

The traditional role of *Geography* has been mainly that of describing regions, including bio-physical as well as socio-economic and cultural characteristics. Turner (2002) uses the term 'chorography' to describe this version of Geography. The proper way of describing a region was formalized in the 19th century in the so called 'catalogue method', still known to many from primary school Geography. The 'catalogue method' approach to describing a region is ordered, so that geological, climatic, topographic and vegetation characteristics are first described, followed by accounts of economic activities and cultural characteristics. Sometimes a causal relationship has been suggested, implying that bio-physical factors, such as climate, determine the socio-economic and cultural characteristics. This has been termed 'natural' or 'environmental determinism'. Early 20th century Geography is often associated with environmental determinism yet in its strictest form it is doubtful whether it ever played a major role in Geography (Christiansen, 1968; Turner, 2002).

The predominantly descriptive tradition of Geography came under fire in the mid 20th century: It was claimed that Geography needed to give up its focus on the 'unique', and instead start looking for universal regularities and laws, as 'real sciences' were supposed to do. This move from an 'ideographic' approach to a 'nomotetic' could not be based on environmental determinism, and instead an old idea, dating back to Kant, of defining Geography as a 'spatial' or 'chorological' science, that is a science focusing on spatial distributions and organization of phenomena, gained support. This obviously implied that the traditional focus of Geography on Human-Environment relationships lost its defining status. In universities where the chorological version of Geography became dominant, the rationale of keeping together the sub-disciplines of human and physical Geography faded, and Geography was often split into two parts. However, with the increasing interest in environmental problems from the 1960's and onwards, the Human-Environment Geography received increasing attention again. It received important inspiration from the new Systems Ecology, and it was seen by some as 'Human' or 'Cultural Ecology' (Christiansen, 1968).

Already in the 1920's it had been suggested that Geography was, effectively, Human Ecology, thereby signalling its integrative role between the natural and human sciences (Barrows, 1923). Barrows drew attention to the problem that Geography was a 'vibrant science', the scope of which had been changing permanently, yet he found that Geography could find its permanent niche in the jungle of disciplines, if it defined its subject as that of "*dealing with the mutual relations between man and his natural environment*", particularly "*from the standpoint of Man's adjustment to environment*". This emphasis on human adaptation to the Environment, clearly inspired by Anthropology, changed during the revival of Human-Environment Geography from the 1970's and onwards, where the theme of 'Man's role in changing the face of the Earth', dating back to George Perkins Marsh's *Man and Nature Or, Physical Geography as Modified by Human Action* (Marsh, 1864) came back in focus. To this date Geography still struggles with the schism between spatial-chorological and Human-Environment interpretations of the discipline, as discussed in more detail by Turner (2002).

As mentioned above, *Human Ecology* played an important role in the evolution of Geography, yet besides that it had a history of its own. The term 'Human Ecology' was introduced in 1913 and has survived nearly hundred years of scientific development, although used in various meanings (Young, 1974; Borden et al., 1986). It is still widely used, both as the name of scientific journals, learned societies (first of all the Society for Human Ecology), multidisciplinary research groups or centers, and educational activities. There are hundreds of Human Ecology institutions around the world, and most of them focus on environmental problems with a normative and problem oriented approach.

The original use of the term Human Ecology goes back to the Chicago sociologists Robert Ezra Park and Ernest W. Burgess (Park & Burgess, 1921). Park (1936) was influenced by the science of Ecology, particularly the quasi-organismic understanding of the ecological 'webs of life' founded by Frederic Clements (1916) and Arthur Thompson (1920), and the community approach by Charles Elton (1927). Park defined Human Ecology as the study of the interaction of four factors: the human population, artifacts ('*technocological culture'*), custom and beliefs ('*non-material culture'*), and the natural resources. He believed that the mutual influences of these four factors together sometimes uphold a biotic balance and a social equilibrium, and sometimes causes transitions. It is the maintenance and disturbances of these balances and the subsequent transitions, which, according to Park, is the proper subject of Human Ecology. The research programme of Human Ecology that originated from Park's ideas has remained rather broad and vaguely defined. It may be seen as a branch of Sociology or Urban Geography trying to make use of ecological concepts such as 'community', 'niche', 'adaptation', 'equilibrium', 'symbiosis', 'territory', 'dominance', 'competition', 'succession', 'climax', etc. (cf. also Hawley, 1986).

Within anthropology, Human Ecology, and the slightly more specific 'Cultural Ecology', developed more or less independently. The focus here was, again, on human adaptation to the bio-physical environment. Bennett (1976) summarizes the history, strengths and weaknesses of the human ecological 'school' of anthropology, and we will not repeat his analysis here. His main contributions are to point to the pitfalls of importing ecological concepts into the social sciences without acknowledging the specific character of human actors and social systems and their ability to respond strategically to any challenge facing them, a finding of high relevance to the current discussions of adaptation to climate change.

Along a third trajectory, Human Ecology developed into yet another kind of interdisciplinary construct with a specific focus on the relationship between human beings and their environment, seen from the side that Barrows mentions but does not develop, that of humans' influence on the environment. This becomes particularly important from the second half of the 1960's with its strong focus on environmental problems. Human Ecology was re-invented by a number of authors, who saw it as a necessary interdisciplinary meeting place, a sort of subversive science, where the still more pressing environmental problems of the current world could be dealt with. Not necessarily as a separate discipline with its very own distinct curriculum. Paul Shepard (1967) put it this way: "*It will be healthiest perhaps when running out in all directions. Its practical significance may be the preservation of the earth and all its inhabitants*". From the late 1960's and throughout the 1970's a large number of books and reports were published within this tradition. Some of the most significant of these were Paul & Anne Ehrlich and John P. Holdren's books "*Population, resources, environment: issues in human ecology",* "*Human Ecology"*, and "*Ecoscience"* (Ehrlich & Ehrlich, 1970; Ehrlich et al., 1973, 1977). Apart from the interdisciplinarity, combining the traditionally separate fields of natural and social science, the most significant features of this tradition are probably the problem orientation and the strong normative or ethical approach (Arler, 2002). The idea was not necessarily to present a coherent model of the many-sided interrelationship between humans and their environment, but rather to analyze and tackle a growing number of problems related to the expansion of humankind on a finite planet.

The public focus on environmental problems that has been increasing since the 1960's, has also given rise to an expansion of a number of related kinds of environmental research. Some have developed within the traditional disciplinary framework in academia, e.g. in biology/ecology, environmental chemistry and environmental economics. However, the need to cross disciplinary boundaries increased and gave rise to the establishment of university departments or 'centers' termed *Environmental Studies* (or 'Environmental Science'). Especially in North America, Environmental Studies has replaced Geography at many universities. The actual activities of departments/centers of Environmental Studies differ greatly, however, both with respect to the type of problems addressed in research and with respect to the types of courses offered. The balance between natural and social science components differs considerably as well. Environmental Studies is often organized as graduate schools, receiving graduate students from a variety of traditional disciplines.

Environmental Management (or 'Environmental Planning') differs often, but not always, somewhat from Environmental Studies due to its more pragmatic or technical approach. Whereas Environmental Studies is often dominated by natural scientists like biologists, chemists and geologists, supplemented by researchers from various social sciences and the Humanities, Environmental Management is more related to traditions of City and Open Land Planning or to Civil Engineering, which, until recently, were not part of the university curriculum. Many traditional universities still do not include these areas. Instead, they have often entered the university world through the back door during the latest decades, as most polytechnical schools have achieved university status.

In Environmental Management a typical approach is to integrate different types of knowledge, which elsewhere are kept separate in various traditional disciplines, by the use of various planning schemes, assessment procedures, and management tools, many of which have been promoted by international organizations and integrated into public policies and corporate strategies (Kørnøv et al., 2007). Typical examples are Life Cycle Assessment, Corporate Environmental Management, Energy Systems Analysis, and Environmental Impact Assessment. This approach is more pragmatic and technical than the generally more theoretical ones found in the other interdisciplinary constructs with origins in traditional university disciplines.

Ecological Economics is a newer construct, dating back to the late 1980's. In one of the first 'readers' on Ecological Economics, with the sub-title 'The Science and Management of Sustainability', some of its founders, Costanza et al. (1991), briefly describe Ecological Economics as a new transdisciplinary field of study that "*addresses the relationships between ecosystems and economic systems in the broadest sense".* Even though these relationships *"are central to many of humanity's current problems and to building a sustainable future"* they *"are not well covered by any existing scientific discipline*".

The sub-title is worth noticing as it signals a 'field of study' which is normative, with the promotion of sustainability as its objective. The 'field of study' is intended to bridge the gap between social science, mostly represented by Economics, and natural science, mostly represented by Ecology. In this respect it has similarities with 'Environmental Economics', and some authors find it hard to distinguish the two (Pearce, 1998), yet the acknowledgement by most ecological economists that 'value' can not and should not be measured in monetary units alone is probably the main point separating the two traditions.

Ecological Economics is termed a 'trans-disciplinary field of study', characterized by a certain 'world view', yet having no well-defined object of study. Like Human Ecology it does have its own journal and a Society, and in spite of the wide spectrum of activities gathered under the heading it maintains a certain degree of coherence. It attracts scientists not only from Economics and Ecology, but also from Geography, Engineering, Law and Philosophy, among others. Research groups and whole departments have been established at several universities under the heading of Ecological Economics.

Sustainability Science is an even newer construct, dating back no more than around 10 years (Clark & Dickson, 2003). Like current Human Ecology and Ecological Economics it is problem-driven and normative in character by making the promotion of sustainable development its objective (Kates et al., 2001). It resembles Ecological Economics in its emphasis on the policy and implementation dimension. It is intended to be broader in scope than Ecological Economics by drawing upon a wider range of traditional disciplines. Whether this is actually achieved is hard to judge, and the overlap with Human Ecology and Ecological Economics is considerable. The point of departure is frequently stated to be 'the study of complex socio-natural systems', and the focus is on understanding 'system properties', such as vulnerability, resilience and adaptive capacity.

Global warming and the enormous challenges associated with it has been a major driver behind the emergence of the Sustainability Science construct. While Sustainability Science has now its own commission under the National Academy of Science in the US and seems presently to constitute a vantage point for interdisciplinary science globally, it remains uncertain whether it will prove able to attract the interest of the human sciences to the necessary extent. The great reliance on systems analysis thinking and vocabulary may be a disadvantage in this respect, since the 'structuralist' and natural science bias of systems analysis tends to discourage many from social science and the Humanities.

The use of the systems analysis vocabulary can also be found in *Earth System Science* (Schellnhuber, 1999), even to the extent that it is included in its name. In most interpretations, Earth System Science does include social science elements. Pitman (2005), for instance, writes that "*Earth System Science is the study of the Earth as a single, integrated physical and social system. Earth System Science views the Earth System holistically based on the understanding of the processes, non-linearities and feed-backs which dominate the system and contribute to emergent phenomena*". However, in some interpretations it is strongly biased towards the natural sciences, offering a framework for integrating Geophysics, Geo-biochemistry and parts of Geology, Physical Geography and Ecology, as illustrated by the definition given in Johnson et al. (2000): "*Earth System Science views the Earth as a synergistic physical system of interrelated phenomena, processes and cycles*". The current great interest in Earth System Science is obviously motivated by the observed global environmental and climatic effects of human activities that evidently cannot be dealt with adequately within the boundaries of a single discipline.

All the above interdisciplinary constructs, apart from Geography, share certain characteristics associated with the ambition to contribute to understanding the challenges of sustainable development and global environmental and climate change. They all attract interest from both natural and human sciences, yet their roots in certain of these disciplines often remain clearly visible. They have all been promoted by some of their adherents as potential new disciplines, but none of them can be said to have obtained this status globally. The various frameworks have appealed to different groups of researchers. This may simply be an expression of a pragmatic diversity of interests and innovative attempts, but it may also indicate that the inertia of the traditional organization of academia is quite forceful. Most students are still trained in traditional disciplines, and personal academic success is often closely linked to membership of a discipline. Since the success in academia of a young scientist is linked to strict adherence to traditional disciplinary standards, it is evident that interdisciplinary activities that disregard some of these standards do not promote success, to which can be added the extra costs of having to get to grips with two or more disciplines.

What separates disciplines?

Apart from the sociological and institutional obstacles faced by interdisciplinary approaches it is also necessary to relate to a number of internal problems of a kind, which may be called epistemological or conceptual. The first problem is whether there are certain features uniting all kinds of science, and which make it easier to cooperate across traditional disciplinary borders.

Most scientists (including practitioners of both natural, technical and social sciences, as well as the Humanities) would accept that there must be a certain 'unity of science' in the sense of a shared set of criteria, which allows us to distinguish between science and non-science. Many textbooks of 'theory of science' discuss what these criteria might be. However, if a definite set of criteria can be identified at all, it must be extremely general and flexible. After all, they have to cover activities as different as, say, the study of Literature, Anthropology, Economics, Medicine, Law, Biology and Physics.

The dividing line between what counts as science and what is left out is difficult to compare in such dissimilar fields of study. The exact placing of the line partly depends on the character of the subject matter at hand, partly on social conventions and practices which could have developed otherwise. Sometimes it is claimed that science is united on the methodological level, for instance that a generalized hypothetical-deductive method is used in all scientific disciplines (Faye, 2002). While this position may be defended, it is obvious that practices differ so widely that an answer to the question of whether all scientific methodologies can be interpreted as variants of the hypothetical-deductive method does not have any bearing on the scientific practise itself.

One of the places where problems of compatibility between disciplines are most apparent is when the concept of 'explanation' turns up. Much science, natural as well as human, revolves around providing explanations of phenomena. Different branches of science use and accept different types of explanations and both within and between natural and social sciences there are different and conflicting standards. We will briefly discuss the use of causal, functional, intentional, and narrative explanations in different branches of science dealing with the Human-Environment relation.

While causal explanations may be found in all sciences, functional explanations are most common in biology and (less so) in the social sciences, but normally not allowed in physics. Functional explanations involve explaining a phenomenon by its function, e.g. the existence of a human body-part by the function it performs. Intentional explanations are only accepted in the human sciences, since they may contribute to the explanation of a phenomenon or an event by pointing to the conscious action of a person or group of persons. Many phenomena dealt with by the human and social sciences are not really intended by anybody, however, or their meaning and significance cannot be reduced to the intentions involved, but may still become meaningful and logical, when interpreted as part of one or more narratives, some of which may still be open-ended at the time of writing. For example, a social event may be interpreted as an early instance of a phenomenon that later becomes common due to the unfolding of previously neglected potentials. Such narrative explanations are useful in order to cope with social processes that no-one fully intended before they occured.

The broad palette of explanation types is particularly necessary to have at one's disposal, when research takes place at the Human-Environment interface. Phenomena and events seldom have singular, well-defined causes, and the explanations involved in understanding complex issues, such as global climate change and the human response to it, obviously encompass all the four categories mentioned. Relationships between phenomena often include feed-backs, blurring the distinction between causes and effects.

In such contexts the notion of 'systems' are often introduced. Complex systems may best be viewed as organized in a 'nested' or 'hierarchical' way, where each 'system' consists of interacting 'sub-systems', which in turn consist of interacting 'sub-sub-systems', and so on. If the system studied is a complex Human-Environment system, each sub-system may be of a more 'purely' abiotic, ecological or social kind. The challenge of integrating different types of explanation thus becomes apparent in 'systems approaches'.

Systems analysis and 'modelling' are closely related, as models may be defined as simplified representations (e.g. in graphic, mathematical or numeric form) of parts of reality, and particularly 'systems'. In many disciplines, natural and social sciences alike, models play a large role, yet the terminology of models and modelling is extremely diffuse, and little systematic discussion of it, outside and above each discipline, can be found. Models used in geophysics (e.g. hydrodynamic models) are simplified representations, based on a combination of basic physical laws and empirically determined regularities within the complex systems, such as the atmosphere or the ocean, reflecting the causal-cum-functional explanations we normally give of these systems. In contrast, the models used in the social sciences need to represent, obviously in a simplified form, the role of human agency, decision making and rational planning. In economics, a discipline known for its strong reliance on mathematical and numerical models, human agency is sometimes reduced to 'Economic Man' assumptions, representing humans as relatively mechanical creatures, who try to optimize satisfaction of their own individual preferences.

In some social sciences the very use of mathematical/numerical models is regarded as reductionistic, not allowing a proper and sufficiently complex account of human agency. From a more pragmatic viewpoint, models constitute hypotheses about the world, and as such necessarily simplify matters. This implies that the question of whether a model's representation of human agency is sufficiently complex depends on the use of the model. If the model actually predicts human behaviour to a satisfactory degree for a specific purpose, it can be useful, even if it cannot be considered a 'valid' representation of the system.

It is clear that the very notion of systems, models and modelling constitutes a dividing line in science: The use of models and the systems analysis vocabulary is a cornerstone in the natural sciences as well as in economics, while it is regarded with much scepticism in other disciplines. Therefore the extensive use of the vocabulary of models and systems analysis in certain Human-Environment constructs may create problems of engaging certain disciplines in interdisciplinary activities.

Differences in normative positions, world views and time perspectives

The differences between disciplines with respect to methodologies and the use of explanations and models are likely to constitute barriers for communication in interdisciplinary research. These differences are often combined with certain 'pre-analytic assumptions' associated with different disciplines. A few examples will suffice.

The research themes and problems addressed by various disciplines and interdisciplinary project groups are usually not chosen by way of 'objective' and easily described rational procedures. What is considered interesting to researchers at a given moment of time is a result of internal disciplinary histories and fashions, as well as of external factors, such as shifting political or societal demands, which are likely to be reflected in the availability of funding.

Normative or ethical positions of the individual researcher and his/her community often play a significant role in the selection of both subjects and methods. For instance, most economists are trained to apply an anthropocentric utilitarian view. Species and ecosystems are analyzed as actual or potential suppliers of economic value, which is a function of individual consumers' 'willingness to pay'. On the other hand, biologists may be inclined towards a more deontological view which focuses on obligations towards other species or ecosystems, or maybe even towards 'Nature' itself (whatever this may designate). For many biologists 'naturalness', 'wilderness', and 'ecological integrity' are basic values, which cannot be reduced to particular groups' non-rational preferences. Such views often appear fairly self-evident to the individual researcher and the group to which (s)he belongs, yet they may appear quite exotic to scientists from other disciplines.

The notion of a 'world view' may be relevant in this connection. Again, the difference between of economics and ecology is quite illustrative (cf. Costanza et al., 1991). The fundamental 1st and 2nd laws of thermodynamics provide an 'ecological' framework for understanding the flows of matter and energy underpinning society, yet these are incompatible with the standard description of the 'economic cycle' in economics, assuming no physical limits to growth. There are, of course, theoretical ways of reconciling the two descriptions, as attempted in 'Ecological Economics', yet the two apparently incompatible world views each constitute part of the deep foundations of their respective disciplines. If ecologists and economists are unaware of this basic incompatibility, they may have problems working together.

The time scales considered in different sciences vary widely, and part of the socialization of a scientist within a discipline is associated with focusing attention to processes with a certain range of time scales: Geologists are trained to focus on processes with very long time horizons, often millions to billions of years. Evolutionary biologists consider processes operating within time horizons relevant to evolution, many thousands to millions of years. Conservation biologists, trying to protect currently existing species and ecosystems study phenomena with a shorter time perspective. Historians may consider the latest few millennia, but often only count in decades or centuries. Economists are seldom interested in time scales of more than few decades.

When studying and discussing issues such as global warming, the disciplinary background of the scientists, specifically as concerns their time horizons, appear to influence their perspectives and attitudes. Some geologists may consider current climate change a fairly insignificant incident compared to what has happened over periods of hundreds of thousands to hundreds of millions of years. Many biologists direct their attention to the issue of the current accelerated irreversible loss of species at time scales of hundreds of years. Some economists totally disregard impacts that are more than 50 years into the future due to the practice of discounting. Such differences in time horizons, while impacting perspectives and attitudes profoundly, may not be recognized by the scientists themselves, as they are part of their 'pre-analytic assumptions', yet they possibly constitute important barriers to understanding between scientists with different backgrounds.

Conclusions

The brief survey of interdisciplinary constructs at the Human-Environment interface demonstrates that new ways are constantly sought to respond to the requirement for scientific understanding and scientifically-based problem solving which cut across traditional disciplinary and faculty boundaries. Climate change research may provide the most obvious example, as it increasingly causes integration of insights and methods from disciplines as far apart as geophysics, systems ecology, environmental economics, sociology, political science, anthropology and ethics. This requirement has spurred the development of a number of constructs, which, while strongly overlapping and addressing many of the same problems, all reflect a wide variety of disciplinary legacies. From Geography and 'Human Ecology' to 'Sustainability Science' they all attempt to come to grips with the fundamentally different standards and epistemological positions of the traditional disciplines. While the multitude of constructs, some replacing each other and some running in parallel, may be confusing, a consistent trend may be observed towards an understanding of the inadequacy of maintaining the traditional barriers between disciplines and faculties when dealing with real-world phenomena such as climate change.

We have attempted to identify differences between disciplines which tend to cause particular problems when carrying out interdisciplinary research (and teaching) on Human-Environment relationships. We suggest that the scientific language and jargon may create barriers, as exemplified by the use of systems analysis and model terminology which tend to discourage social scientists, yet this may well reflect deeper differences related to the types of explanations preferred or accepted in the various disciplines. Further, differences in value-sets, pre-analytic assumptions, world views, and preferred time-scales represent barriers. Such differences are reproduced through standard disciplinary socialization of young researchers, as adherence to your discipline's standards is a precondition for academic success.

If the importance of these obstacles to effective interdisciplinary research is accepted, and if it is true that scientists are often unaware of their existence, one logical consequence is that efficient interdisciplinary research presumes that they are brought to the surface and made visible. This requires that young scientists are trained in epistemology and methodology, beyond what is typically considered relevant to the discipline in which they are socialized. Further it may be necessary to provide institutional support to inter- or transdisciplinary research groups in order to avoid that effective collaboration is hampered by lack of awareness of such barriers.

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